Physics Motivations for Future Colliders

Pyungwon Ko (KIAS)

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No-lose theorem for LHC

- Before the Higgs boson discovery, rigorous arguments for LHC due to the No-Lose theorem

- W/o Higgs boson, $W_L W_L \to W_L W_L$ scattering violates unitarity, which is one of the cornerstones of QFT

- Unitarity will be restored by
  - Elementary Higgs boson
  - Infinite tower of new resonances (KK tower)
  - New resonances for strongly interacting EWSB sector
  - Higgs is there, but not observable if it decays into DM (2007,2011,..)

My personal favorites

- So far, all the observed fermions are charged under some gauge symmetries, and chiral

- All the matters are fundamental representations of the gauge group. No higher dim rep.’s have been found yet

- Dark photon, dark Higgs (~singlet scalar) if DM mass ~ EW scale

- Vectorlike fermions which are chiral under new gauge sym

- New confining (dark) forces

Personal Viewpoints

- Higher energy colliders can produce heavier particles and probe shorter distance : $E = Mc^2$, $\Delta x \Delta p \gtrsim \hbar$

- No rigorous arguments to set new energy scales, unlike before the Higgs boson discovery

- Unexplored territory of the SM : Nonperturbative aspects such as QCD instanton, EW sphaleron

- Can we set a new energy scale for pp colliders so that we can measure the Higgs aquatic coupling within certain accuracy ?

- Model independent approach based on SMEFT ? Could be misleading if used for high energy colliders

- Many UV completions for a given EFT operator in general

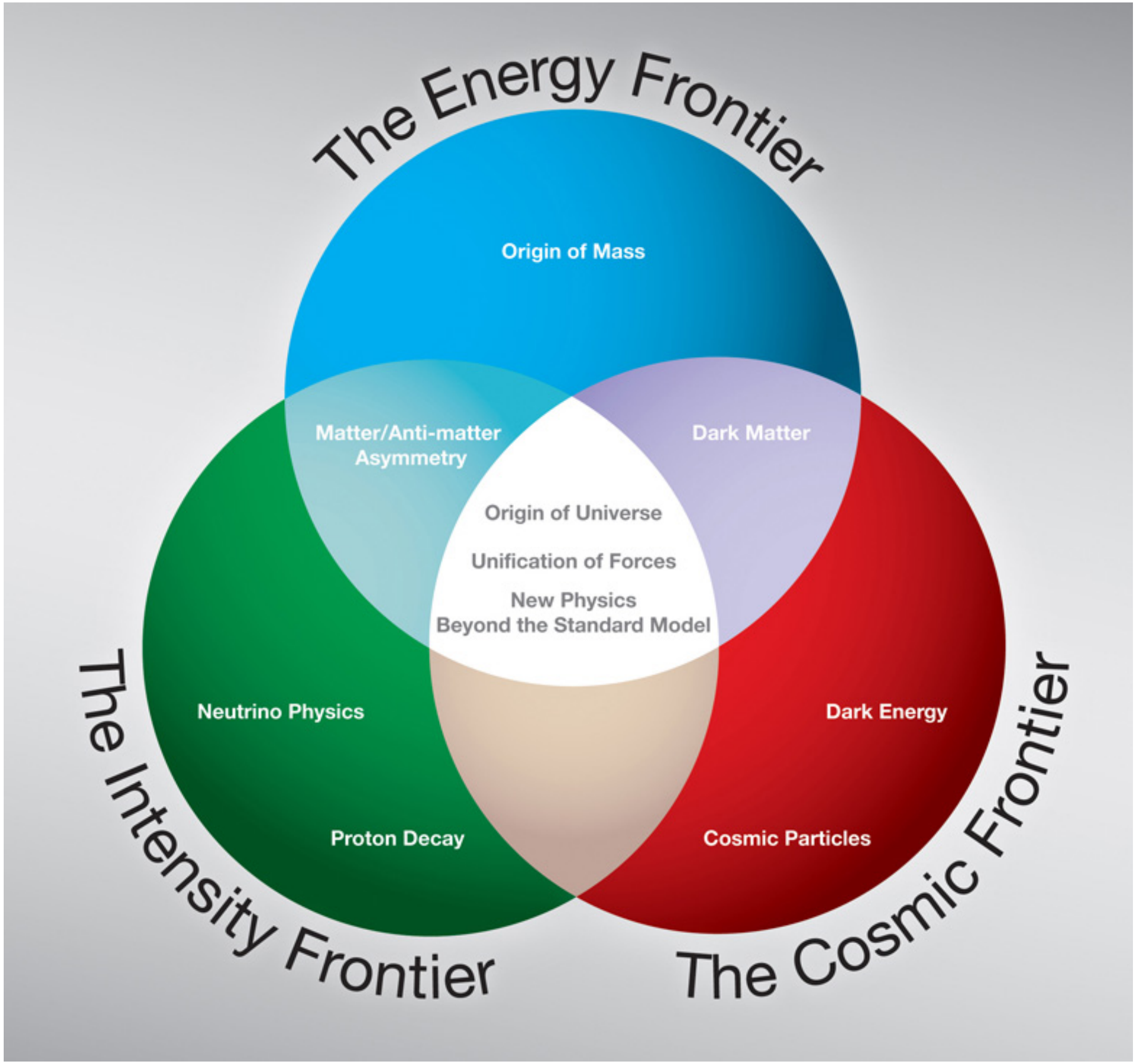
- Model dependent approaches motivated by the current anomalies, such as muon g-2, RK(*), RD(*), neutrino masses and mixings, dark matter, etc.

- Some interesting channels: DY + missing ET, Multi leptons (+ missing ET), $t\bar{t}$ + missing ET, etc.

- In any case, search for New Physics without any theoretical prejudice is most important (SUSY, MSW with the large mixing for the solar neutrino problem, etc.)

Some recolletion

- $B \to J/\psi\pi\pi$ for D-wave charmonium $\to X(3872)$ (1997)
- $U(1)_{\mu-\tau}$ for the muon $(g-2)$ (2001) and PAMELA e^+ excess (2009)
- Invisible Higgs decay into DM pair in the hidden valley scenario (2007, 2011)
- Higgs invisible decay in Higgs portal DM (2007,2011,2014)
- $t-$channel mediated DM search at colliders (2017)


The Energy Frontier
Origin of Mass
Matter/Anti-matter Asymmetry
Dark Matter
Origin of Universe
Unification of Forces
New Physics Beyond the Standard Model
Neutrino Physics
Dark Energy
Proton Decay
Cosmic Particles
The Intensity Frontier
The Cosmic Frontier